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INVENTION DISCLOSURE

THIS INVENTION DISCLOSURE IS MADE PURSUANT TO MY / OUR INVENTION AGREEMENT WITH HUGHES AIRCRAFT COMPANY.

B-3996

HUGHES

1. TITLE OF INVENTION

Symmetric, Planar Spiral Inductor

2. INVENTOR(S)

NAME	PAYROLL NO.	SOURCE CODE	LOC	BLDG	MS	PHONE	MANAGER
Gopal Raghavan	J3230	30-31-10	MA	250	RL61	317-5265	W. Stanchina
Michael G. Case	J3206	30-31-10	MA	254	RL61	317-5793	W. Stanchina

This is to acknowledge that the above Invention Disclosure has been received by Corporate Patents and Licensing. The disclosure will be reviewed at the next Evaluation Committee Meeting of your organization and you will be promptly informed of the results. If you have any questions please contact the patent attorney listed on the bottom of this form.

This sheet will be returned to the inventor(s) as a confirmation of receipt by Corporate Patents and Licensing.

LOSS OF RIGHTS THROUGH RELEASE TO THE PUBLIC

The right to apply for and obtain a valid patent may be lost as the result of certain activities, such as (1) disclosing the invention outside of the company without an appropriate confidentiality agreement with the receiving party; (2) using the invention publicly; (3) using the invention privately to build or test items that are to be sold publicly; or (4) putting the invention "on sale" by selling or offering for sale an item or product that embodies or uses the invention, or is made or tested by use of the invention. Submitting a proposal with the intent to use the invention in the performance of a resulting contract puts the invention "on sale".

Please inform me immediately of any of these activities or any plans to undertake any of them.

ASSIGNED ATTORNEY: PHONE ( )

Symmetric, Planar Spiral Inductor

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PATENT DOCKET NO.

HRL LABORATORIES
MAY 22 2000
PD# 000501

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3. PROOF ON CONCEPTION

A. BY WHOM WAS FIRST DESCRIPTION WRITTEN OR DRAWING MADE?	DATE	TIME SPENT	ACCT. CHARGED	LOCATION OF FIRST DESCRIPTION / DRAWING
G. Raghavan	1/10/2000	1 Hour	CD003351L	IE3D EM Simulator, computer
B. TO WHOM WAS INVENTION FIRST DISCLOSED?	DATE			
Michael G. Case	1/10/2000			

4. REDUCTION TO PRACTICE

A. WAS A DEVICE EMBODYING THE INVENTION CONSTRUCTED AND TESTED OR THE PROCESS PRACTICED?	YES / NO X	BY WHOM	DATE STARTED	DATE COMPLETED	TIME SPENT
B. ACCOUNT CHARGED — TIME	ACCOUNT CHARGED — MATERIAL		PRESENT LOCATION OF DEVICE		
C. PRESENT LOCATION OF DOCUMENTS (DATE SIGNED AND WITNESSED), INCLUDING PHOTOS, DRAWINGS, AND DATA SHEETS SHOWING REDUCTION TO PRACTICE					

NOTE: ALL EVIDENCE OF CONCEPTION (FIRST DRAWING AND FIRST WRITTEN DESCRIPTION) AND EVIDENCE OF REDUCTION TO PRACTICE (DEVICE EMBODYING THE INVENTION AND TEST DATA) MUST BE RETAINED.

5. RELATION TO GOVERNMENT CONTRACT

A. DOES THIS INVENTION RELATED TO WORK PERFORMED UNDER A GOVERNMENT CONTRACT?	YES ☐ / NO X	CONTRACT NUMBER AND TITLE
B. IS INVENTION BEING USED ON A GOVERNMENT CONTRACT?	YES X / NO	CONTRACT NUMBER AND TITLE BD84J1

6. RELATED DOCUMENTS AND DISCLOSURE (BY YOU OR BY ANOTHER). PLEASE ATTACH COPY.

		DATE	IDENTIFY
A. IS THERE A PUBLICATION OR PUBLIC PRESENTATION RELATED TO THE INVENTION?	YES ☐ / NO X		
B. ARE THERE ANY RELATED INVENTION DISCLOSURES OR PATENT APPLICATIONS?	YES ☐ / NO X	DATE	IDENTIFY PD NO. ETC.
C. ARE THERE ANY PROPOSALS OR REPORTS OR OTHER DOCUMENTS RELATING TO THIS INVENTION	YES ☐ / NO X	DATE	IDENTIFY
D. HAS THE INVENTION BEEN USED, DISCUSSED, DEMONSTRATED OR OTHERWISE DISCLOSED OUTSIDE THE COMPANY (SUCH AS TO A VENDOR OR CUSTOMER)?	YES ☐ / NO X	DATE	TO / FOR WHOM (COMPANY / PERSON)

7. SALE

		ORDER NO.	ORDER DATE	DELIVERY DATE	DATE OFFERED OR PROPOSED
A. HAS PRODUCT EMBODYING INVENTION OR MADE BY INVENTION BEEN PROPOSED, SOLD, OR OFFERED FOR SALE?	YES ☐ / NO X				
B. IS PRODUCT EMBODYING INVENTION OR MADE BY INVENTION IN A DELIVERABLE ITEM?	YES ☐ / NO X	DELIVERY DATE			

SIGNATURE INVENTOR — DATE 5/17/00

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8. SUMMARY OF THE INVENTION

A. GIVE A BRIEF DESCRIPTION OF YOUR INVENTION, PARTICULARLY POINTING OUT WHAT IS BELIEVED TO BE NOVEL (THE "HEART" OF WHAT IS NEW).

Our implementation of a symmetric planar spiral inductor eliminates inherent asymmetry by winding the inductor as concentric circles rather than a spiral. This preserves the mutual inductive coupling needed for the inductor, while eliminating the asymmetry associated with a true spiral.

B. EXPLAIN THE PURPOSE AND ADVANTAGES OF YOUR INVENTION. (WHAT WILL THE INVENTION DO BETTER THAN DONE PREVIOUSLY?)

Planar spiral inductors have been used for integrated circuits since the early 1970's (US03765082). All such inductors have been designed with an intrinsic asymmetry since one terminal of the inductor is at the outside of the spiral, while the other terminal is on the inside. This asymmetry usually does not cause any concern for circuits using single-ended signals, i.e. where the signal voltage is relative to ground or a fixed potential. Many new circuits and systems use differential signals where the signal voltage is the difference between two terminals. Any asymmetry in differential circuits degrades the signal quality, hence is very undesirable.

C. IDENTIFY THE COMPANY PROGRAM OR PRODUCT LINE TO WHICH THE INVENTION APPLIES, AND THE EXPECTED VALUE TO THE PROGRAM OR PRODUCT LINE. ALSO IDENTIFY POTENTIAL COMMERCIAL APPLICATION OF THIS INVENTION, INCLUDING AUTOMOTIVE APPLICATIONS, IF ANY.

This invention is currently being used in a band-pass delta-sigma analog-to-digital converter as part of a resonator. This project is funded by a contract through wright labs. Such an inductor is useful in general for any circuit where differential signals are being used.

D. IDENTIFY THE PRIOR ART KNOWN TO YOU WHICH IS IMPROVED UPON OR DISPLACED BY YOUR INVENTION, AND STATE IN DETAIL, IF KNOWN, THE DISADVANTAGES OF THE CLOSEST PRIOR ART.

There are many examples of inductor patents, but many refer to the standard, asymmetric spiral inductor and how to improve one or another characteristic such as increased Q, reduced size, etc. (US03765082 10/16/1973 METHOD OF MAKING AN INDUCTOR CHIP, US05656849 08/12/1997 Two-level spiral inductor structure having a high inductance to area ratio US05805043 09/08/1998 High Q compact inductors for monolithic integrated circuit applications, US05793272 08/11/1998 Integrated circuit toroidal inductor, US05884990 03/23/1999 Integrated circuit inductor, US06008713 12/28/1999 Monolithic inductor, US06054329 04/25/2000 Method of forming an integrated circuit spiral inductor with ferromagnetic liner, US06013939 01/11/2000 Monolithic inductor with magnetic flux lines guided away from substrate).

SIGNATURE INVENTOR		DATE 5/17/00
SIGNATURE INVENTOR		DATE 5/17/00

READ AND UNDERSTOOD BY:

WITNESS NAME (TYPE) Tommy Luna	SIGNATURE Tommy Luna	DATE 5/17/00
WITNESS NAME (TYPE) Ara Kurdoghlian	SIGNATURE Ara Kurdoghlian	DATE 5/17/00

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9. DETAILED DESCRIPTION

DESCRIBE YOUR INVENTION IN DETAIL, USING NECESSARY ADDITIONAL SHEETS

A. BE SURE THAT EACH SHEET IS DATED, AND SIGNED BY EACH INVENTOR AND TWO WITNESSES. (HAC FORM 236C-6 CS SHOULD BE USED, IF PRACTICAL).

B. ATTACH COPIES OF DRAWINGS OR DETAILED REPORTS HELPFUL IN UNDERSTANDING HOW YOUR INVENTION WORKS

C. IF YOUR INVENTION HAS BEEN TESTED, BRIEFLY SUMMARIZED THE TEST RESULTS WHICH CONFIRM THE FUNCTIONS AND ADVANTAGES LISTED IN 8 B ABOVE.

Figure 1 shows a typical spiral inductor as described in practically all prior art (some round, some rectangular, etc.). There is a significant difference between the two terminals since one of the terminals is connected to the outside of the spiral while the other must connect to the inside of the spiral. This configuration also forces the conductor leading to the center of the spiral to cross over (or under) the intervening windings of the inductor, again increasing the asymmetry and adding undesired capacitive coupling. Our invention (Figure 2) comprises a unique method of winding an inductor using concentric circles rather than a true spiral to maintain the magnetic field coupling needed for enhanced inductance, while providing a perfectly symmetric structure. Furthermore, the only crossovers required can be symmetrically placed opposite the inductor's terminals, preserving the symmetry and minimizing undesirable capacitive coupling.

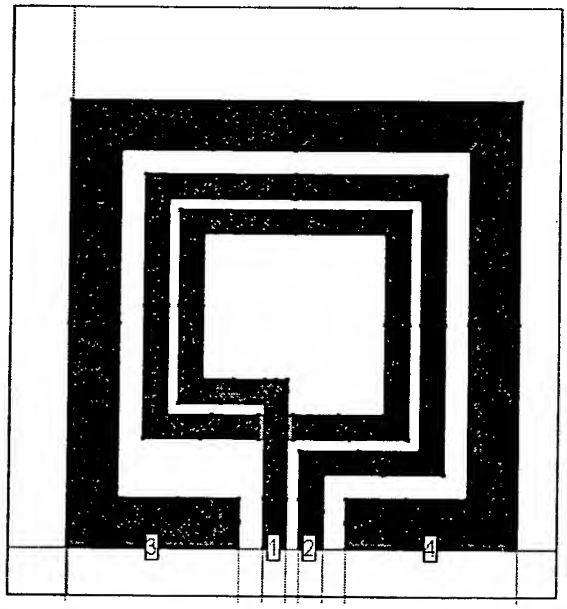

Figure 1. Traditional planar spiral inductor. Asymmetry between the inductor terminals arises since a spiral is not symmetric and port 2 is in closer proximity to the ground than port 1. Numbers indicate terminals for the device: 1 and 2 are terminals for the inductor, 3 and 4 are ground terminals. This inductor is approximately 350 μm square.

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WITNESS NAME (TYPE) Ara Kurdoghlian	SIGNATURE Ara Kurdoghlian	DATE 5/17/00

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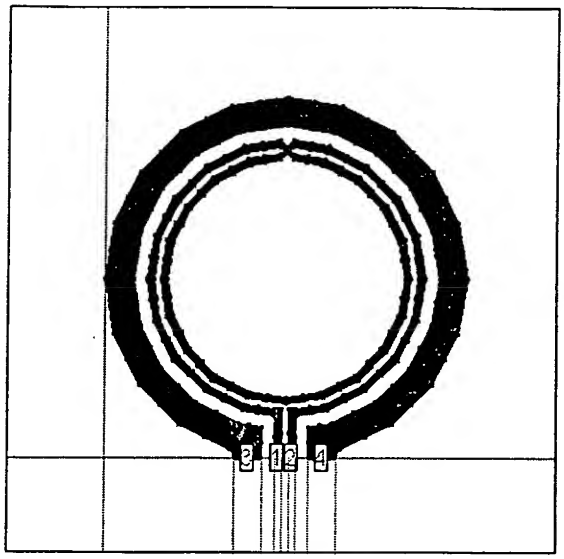

Figure 2. Symmetric planar inductor, this invention. Symmetry is achieved by using concentric circles to wind the inductor instead of a spiral. Here there is perfect symmetry in the construction. This inductor is approximately 450 μm diameter.

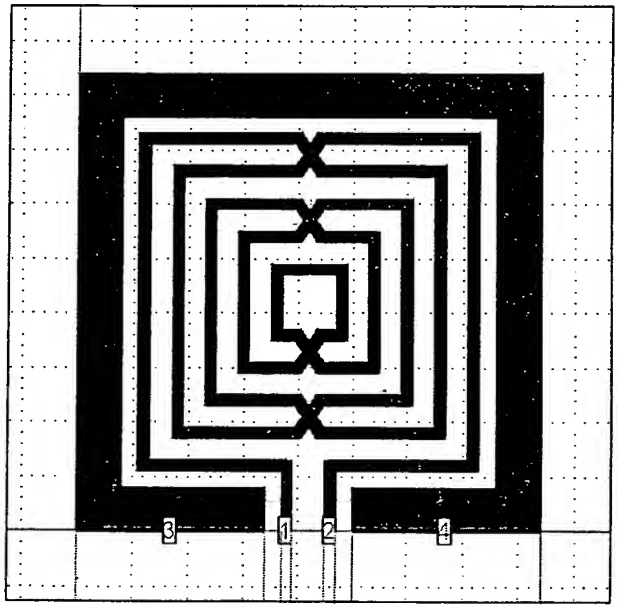

Figure 3. Symmetric planar inductor with a large number of square windings.

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SIGNATURE INVENTOR		DATE 5/17/00

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WITNESS NAME (TYPE) Tommy Luna	SIGNATURE Tommy Luna	DATE 5/17/00
WITNESS NAME (TYPE) Ara Kurdoghlian	SIGNATURE Ara Kurdoghlian	DATE 5/17/00

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This invention can easily be extended to consider any concentric arrangement of arbitrarily symmetric shape (square, hexagonal, etc.) and any number of concentric windings (Figure 3).

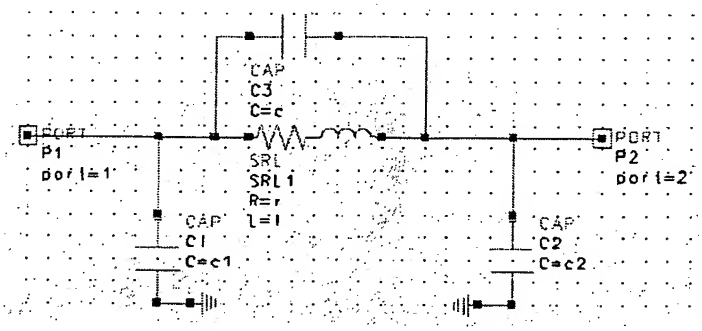

Figure 4. Equivalent circuit for planar spiral inductors. Asymmetry appears as a difference between capacitors C1 and C2.

A typical equivalent circuit for a planar spiral inductor is shown in figure 4. Asymmetry appears as a difference in value between capacitors C1 and C2. We use an electromagnetic simulator to predict the behavior of these inductors, then fit the equivalent circuit parameters to match their characteristics. Table 1 provides equivalent circuit parameters fit to the electromagnetic simulations of the inductors shown in figures 1 and 2. The inductor implementing our invention shows nearly perfect symmetry (0.8%), while the conventional inductor bears a 37% difference between C1 and C2.

Inductor	Fig. 1	Fig. 2	unit
C1	59	103.7	fF
C2	86	104.5	fF
C	3.8	0	fF
L	1.2	2.6	nH
R	2.3	4.5	Ohms

Table 1. Equivalent circuit values for the two inductors shown in Figures 1 and 2. The inductor implementing our invention (Figure 2) shows nearly perfect symmetry (0.8%), while the conventional inductor (Figure 1) bears a 37% difference between C1 and C2.

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READ AND UNDERSTOOD BY:

Tommy Luna — WITNESS NAME (TYPE) — Tommy Luna — SIGNATURE — 5/17/00 — DATE

Ara Kurdoghlian — WITNESS NAME (TYPE) — Ara Kurdoghlian — SIGNATURE — 5/17/00 — DATE

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